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An Examination of Science Education in Different Cultural Settings

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An Examination of Science Education in Different Cultural Settings

By

Rebecca Voler

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An Examination of Science Education in Different Cultural Settings

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Abstract

This paper investigated how science education is implemented in The Gambia, the city of Buenos Aires, Argentina, and Pennsylvania, particularly as it applies to science curriculum and pedagogy. To compare how science education is implemented in these three different regions, a wide range of data was collected. Interviews were conducted with educators and administrators in both The Gambia and Argentina. Faculty members were interviewed about their thoughts and insights on their experience with science education, and the strengths and challenges they felt were present in their school. While no faculty members were formally interviewed in Pennsylvania, I was able to learn about science education in Pennsylvania based on my attendance in a science education methods course at Elizabethtown College. In addition to personal anecdotes, whenever possible textbooks, assessments, curriculum documents, science standards, and other relevant data were gathered for comparison.

The results of this qualitative analysis looked to highlight the similarities and differences that exist between the three locations, recognizing that in most cases, best practice varies given the different cultural backgrounds, materials available, and established educational paradigms. Results also demonstrate that that while there were indeed several differences between the countries stemming from three unique cultures and social settings, many of the programs that have been implemented to promote science education have similar goals. However, science teachers in the United States can adapt methods used in Argentina and The Gambia to better fit the needs of their diverse students.

I. Introduction

Science, Science Education, and Scientific Literacy

Science is the study of phenomena and events through systematic observation and experimentation. Science education is vital to foster students' curiosity about the world around them. More than a search for truth, science education develops a way of thinking and problem solving that helps students to grow as individuals while meeting the changes and challenges in our ever-evolving society. Science careers are a path to social mobility, and science is also a means for nations to compete on a global scale. Science is important for economic and societal development worldwide, and along with the related fields of engineering and technology, permeates nearly every facet of modern life, holding the key to the solutions to modern challenges in the United States and around the world. However, the way science is taught can vary drastically due to differences in culture.

Numerous assessments – both national and international – measure students' science learning; however, scientific literacy is not necessarily about a person's ability to memorize facts or equations, but developing an understanding and way of thinking that can be applied in various problem-solving situations both in and out of the classroom. Science literacy in a community does not require individuals to attain a certain threshold of knowledge or skill; rather, it is a matter of that community having the shared capability necessary to address science-related issues (National Academies of Sciences, Engineering, and Medicine, 2016). Roberts and Bybee (2014) distinguish between two types of scientific literacy; Vision One, which prepares students for careers in science and Vision Two, which prepares students to address the authentic socio-scientific issues in our complex and ever-changing world

One step in pushing for a scientifically literate society is the integration of interdisciplinary skills, specifically science, technology, engineering, and mathematics (STEM). This approach to learning encourages curiosity, creativity, and critical thinking rather than the traditional trend of memorizing facts, and thus has grown both in the United States and around the world. STEM education and other paradigms are reshaping the way science classes are taught, but differences in school systems and international educational norms can greatly impact science classrooms, albeit indirectly.

Education in Pennsylvania

In Pennsylvania and most of the United States, education is split into three segments, with students typically attending primary school for grades one to five, middle school from grades six to eight, and secondary from nine to twelve. By Pennsylvania state law, education is compulsory until age 17 (although there are religious exemptions), and free public education is available to all students, although around 10% choose to attend private school (Council for American Private Education, 2016) and about 3% are homeschooled (Coalition for Responsible Home Education, 2019).

Formal science education in Pennsylvania begins in the early grades with an introduction to biology, physical science, earth and space science, and technology. The Pennsylvania System of School Assessment (PSSA) measures progress with a standardized test in grades four and eight (Education.pa.gov, 2019). In high school, students take individual classes in biology, chemistry, and physics, and scoring proficient on the Biology Keystone is a graduation requirement. Many schools offer additional science courses as electives, but enrollment depends greatly on students' individual interests and career or college plans. These standards are specific to Pennsylvania, although there is a national movement to adopt the Next Generation Science Standards (NGSS Lead States, 2013) hereafter referred to as NGSS. Implementation of NGSS in

Pennsylvania would be a move towards the enactment of an integrated STEM approach at all educational levels, but would also require teacher training and a rework of state assessments.

All teachers in Pennsylvania are required to earn a bachelor's degree with a GPA of 3.0 or higher, and hold a teaching license, although different requirements are put in place to teach specific subjects, especially at higher levels. To receive their certification in science, teachers have to pass the Praxis, a series of tests that measure their basic skills in reading, writing, and math, as well as tests in their specific content area. However, due to higher demand for teachers in some urban and rural settings, finding teachers certified to teach high-level science courses can be a challenge for some schools.

Education in The Gambia

Formal education in The Gambia consists of six years of primary (lower basic) and three years of upper basic schooling. After these nine years, students take a placement exam that decides whether they can continue to secondary school, and whose score determines which school they attend. Although lower basic education is free and compulsory, students' families need to pay for their uniforms and supplies, which prevents some children from attending school. The cost is an extra hurdle for girls, for whom parents are less willing to pay when traditionally school is seen as being for males only. However, attendance rates have risen dramatically in the 21st century, and since 2007 the ratio of boys to girls has been equal, although the rate of completion is 74 girls for every 100 boys (UNICEF, 2013).

Upper and lower basic education is free, but students who successfully pass exams in their ninth year have to pay tuition for the three years of secondary education. Some scholarships may be available, but they typically cover less than half of tuition (Binta J., personal interview, May 19 2019). While primary schools mostly focus on teaching mathematics and English reading and writing, secondary school curriculum introduces science, social studies, and several electives, which may include the arts, commerce, and additional science subjects. Each subject is then tested with national exams administered by the West African Examinations Council.

With an urban poverty rate of 31 percent and the rural poverty rate at 68 percent, the cost of education is not only a barrier for students, but also for potential teachers (Gambia Bureau of Statistics, 2017). To be certified, teachers must attend three years of school – one year of classes covering pedagogy and content knowledge, and two years of placement in a classroom (Gardner, 2011). The cost of certification holds back many Gambians, and retention rates are low due to low salaries (Binta J., personal interview, May 19 2019) Demand for qualified teachers is especially high in rural areas, as higher levels of poverty limit schools' resources, and teachers in these settings typically are forced to move away from their family or relocate upcountry where conveniences like hospitals and stores are not readily available (Gardner, 2011)

Education in Argentina

While education in The Gambia is different in its age breakdown and duration, in many ways the basics of education in Argentina are very much like those in the United States. The system consists of four levels: preprimary, primary, secondary, and higher education. However, preprimary education from the ages of 3-5 is optional (Drazer, 2006), and as not all students attend university after graduating from secondary schools, the base education lasts for twelve years. Unlike the elementary, middle, and high schools in the US, these twelve years of education in Argentina are split into two levels, called *ciclos*. Primary level consists of grades one through seven, while secondary is comprised of an additional five grades. The academic year begins in March and ends in mid-December, with the two-and-a-half-month break lining up with summer in the southern hemisphere.

The most significant difference in the Argentinian educational system is the abundance of private schools. According to a census conducted in 2007, approximately one third of students in the province of Buenos Aires attend a private school, with this figure rising to 49% in the city of Buenos Aires (Ministerio de Educación). Since public schools are funded by taxes, why does such a large percentage of families choose to pay to send their children to private school? Although the government does not use standardized tests to measure schools' academic performance, some empirical studies have found that students from private schools consistently perform more strongly and graduate at a higher rate than their public-school counterparts (Vicente, 2017). However, secondary schools in Buenos Aires tend to have similar curricular offerings, and privately funded institutions do not necessarily have access to additional resources. Instead, the most influential factors on student performance include the generally lengthier training for teachers at private schools and the higher socioeconomic level of the students (Fischmann, 2001).

While instructors' level of training can impact their ability to effectively manage a classroom and adapt to best meet their pupils' needs, the social class of the students has a greater effect on the class environment. Upper class students and families have higher expectations of what can be achieved as a result of education. Quantitatively, 51% of Argentines between the ages of 25 and 65 do not have a high school diploma (Formichella, 2011), and 35% live in poverty, with 25.4% of households unable to afford their basic food needs (Buenos Aires Times, 2019). Children growing up in these environments cannot receive the same level of attention and support at home.

This paper will focus on science standards, pedagogies of observed classrooms, examination style, and government programs to promote science education in Pennsylvania, Buenos Aires, and The Gambia. I chose these locations due to my opportunity to do research in The Gambia and study abroad for a semester in Buenos Aires. After growing up going through Pennsylvania's education system and continuing my education to become a teacher in

Pennsylvania, I was interested in what ways science education would differ in the three areas. As a future teacher, I will have culturally and linguistically diverse students in my classroom, and I hope by better understanding the ways teachers in Buenos Aires and The Gambia teach the same content, I might better adapt to create the best learning environment for my students. Science is a key factor in international development, but it is to be expected that science education standards and outcomes may vary greatly due to inequality in available resources, concepts of scientific literacy, and the expectations of society.

II. Literature Review

Science Standards

In the state of Pennsylvania, science standards are defined by the Department of Education, specifying appropriate material and learning outcomes for each grade level (Pennsylvania Board of Education, 2009; Pennsylvania Board of Education, 2010). These documents break science down into five content areas: Environment and Ecology, Biology, Physical Science (chemistry and physics), Earth and Space Sciences, and Technology and Engineering. Furthermore, learning outcomes are broken down to four age groups: Kindergarten through fourth grade, fifth to seventh grade, eighth to tenth grade, and eleventh and twelfth grade. In addition to content-specific standards, Figure 1 of Appendix A shows science as an inquiry standard, with the learning goals broken down in a chart for each age group. The actual content area strands show that while the goals may be appropriate for students starting kindergarten, science isn't a formal part of the classroom until third grade. From third to eighth grade, some form of each of the four content areas is incorporated into science classes. However, once students reach high school, science courses are separated by content area, with one class each for biology, chemistry, and physics (Pennsylvania Department of Education, 2010).

In contrast to the Pennsylvania Standards, the Next Generation Science Standards (NGSS), which were developed by 26 states in 2013 and have since been adopted by 19 states, specifies detailed scientific and engineering practices, disciplinary core ideas, and crosscutting concepts for each grade, starting in kindergarten (NGSS Lead States, 2013). While Pennsylvania is not one of the states to adopt the new standards, the State Board of Education is looking to modernize the current standards, which may be influenced by NGSS (Murphy, 2019). Therefore, it is interesting to compare the difference between the standards, to better understand the changes teachers would have to make were they adopted, either fully or in part.

All the standards are broken down by topics, with learning outcomes that teachers are expected to cover (NGSS Lead States, 2013; Pennsylvania Board of Education, 2010). However, the two documents vary greatly in the amount of detail given. Pennsylvania's Academic Standards list the learning outcomes. For example, in the section on forces and motion of particles and rigid bodies, students are expected to be able to "differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration; use force and mass to explain translational motion or simple harmonic motion of objects; and relate torque and rotational inertia to explain rotational motion" (2010, p 28). However, it is not stated how teachers are expected to achieve this.

In the NGSS Standards for Motion and Stability: Forces and Interaction, performance expectations are broken down into six sections. One is to "analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration" (2013, p 94). This aligns relatively closely with the goals in the currently used standards. However, another expectation is to "plan and conduct an investigation to provide evidence that an electrical current can produce a magnetic field and that a changing magnetic field can produce an electrical current" (p 94). This level of student involvement is not explicitly expressed in Pennsylvania's standards, which focus on content. NGSS envisions science education as a three-dimensional approach consisting of disciplinary core ideas, science, and engineering practices. The standards expand on overall topics to include skills and practices, such as planning and conducting an experiment, or using science principles to design a theoretical device to minimize the force on an object during collision – a real life application of the content covered in class (2013). If the Pennsylvania Department of Education is to adopt some or all of NGSS, it would result in a greater depth of standards, which would cause the need to modify examinations and teacher training to adequately respond to the changes.

With the growth of STEM careers in the United States and around the world, it is increasingly important that a STEM approach is integrated into science standards. This paradigm stresses more than standards and content objectives. STEM standards include everything from heat transfer and the nature of waves to the origin and evolution of the universe (Teach Engineering, 2019; NGSS Lead States, 2013). While standards may be specific to the subject areas in which they are typically taught, STEM unites science, technology, engineering and math with unifying themes and practices which include: developing and using models; planning and carrying out investigations; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information (Feder, 2015; NGSS Lead States, 2013). In Pennsylvania's current model, concepts often cut across various courses. For example, the nature of waves should be taught in grade 10 and physics, with each course covering new material on the same theme (Pennsylvania Board of Education, 2010, p 30). Physics courses may use math, or build on concepts of energy storage and transformation taught in a chemistry course (p 29), but the interrelation of the science fields is not explicitly explained in current Pennsylvania standards, nor are hands-on approaches required, even if many teachers do include labs and design activities as part of their curriculum. One of the strengths of NGSS is a section on crosscutting concepts following the performance expectations, which clearly lays out overlapping ideas from various STEM fields (NGSS Lead States, 2013). Explicitly addressing STEM in reformed standards would better prepare students for a world in which science, technology, engineering, and mathematics permeates every aspect of life.

Exams

Science evaluations have many purposes, including holding educators accountable, notifying teachers and management about student understanding, and demonstrating which science skills and subjects are considered valuable (Feder, 2015; Noble et al., 2012). Regardless of their purpose, examinations greatly influence the way that teachers conduct their classes, as they are seen as a measurement of students' skills and knowledge. Unfortunately, test results show that students have lost ground in math, and there is a great disparity in performance on tests in minority groups (Education Commission of the States, 2018). The achievement gap appears as early as elementary school, and continues to manifest in college through the rates at which minority students pursue STEM degrees (Education Commission of the States, 2018; Noble et al., 2012). For instance, only 7% of college-age students of color earn degrees in engineering, despite making up 22% of the college-age population. In Pennsylvania, engineering degrees and other degrees in STEM fields are disproportionately awarded to white male students (2018).

Noble et al argue this disparity is not due to an academic achievement gap, but a test score gap, as exams do not accurately reflect knowledge (Noble et al., 2012). Culturally and linguistically diverse students – especially English Language Learners – were found likely to answer science questions incorrectly despite demonstrating knowledge of the concepts, merely because the way questions were worded reflected the language patterns and cultural norms of European Americans. This is more challenging because examinations focus on individual assessments, which ask students to recall content and specific knowledge (Feder, 2015; Noble et al., 2012). Test score disparities may also be caused by inequality of resources; according to one study by the U.S. Department of Education, 65% of eighth grade science teachers at majority white schools report they have all the resources they need, while at schools with over fifty percent black or Latino students, only half of science teachers feel they have enough resources (Education Commission of the States, 2018).

While classroom resources may negatively impact students' test scores, one resource available to all Pennsylvania science teachers is the PSSA and Keystone Sampler, a document released every year with retired questions to give educators and those studying for the exams an idea of what to expect (Pennsylvania Department of Education, 2018a; Pennsylvania Department of Education, 2018b; Pennsylvania Department of Education, 2019). These state tests span from elementary school to high school, but are very similar in their layout and question format. Both examinations start with a multiple-choice section, which is followed by a short answer portion. For the latter, responses are scored on a scale of zero to three based on the student showing insufficient, minimal, partial, or thorough understanding of a topic.

While some questions ask students to interpret graphs, such as question 18 on the life cycle of the Gypsy Moth (Pennsylvania Department of Education, 2018, p 35), the PSSA and Keystone Assessments are standards-based tests. The exam measures students' knowledge by asking them to demonstrate comprehension and retention of facts and content, rather than demonstrating skills or abilities in science. While the selection of Samplers does not necessarily cover all possible questions or fully represent Pennsylvania's science assessments, the exams are limited by the nature of the questions, which do not allow students to express the entirety of their knowledge or skillset in the sciences. Multiple-choice questions are easy to grade and are an efficient way to cover a wide range of topics, but do not always accurately measure academic achievement. This style of standardized test has been in practice in Pennsylvania since the early 2000s, but modernization of state standards could in turn help to modernize PSSA and Keystones.

Science Education Pedagogies

When it comes to teaching science standards, a teacher's pedagogy can drastically influence the class's outcome. From behavioral pedagogies to a student-centered, constructivist approach, teaching styles range from lectures to horizontal learning in which the teacher assumes the role of mentor and coach, guiding students to play an active role in their own education. Despite these varied pedagogies, literature agrees that student-centered styles have the most positive impact (Feder, 2015; Zeidler, 2014; Harper, 2017; Falk et al., 2017). Student centered learning is a key component of both socio-scientific inquiry and problem based learning (Zeidler, 2014; Harper, 2017). Socio-scientific inquiry presents students with a complex, real-life example to be answered over the course of a unit by incorporating many points of view to find a multifaceted solution. In addition to tackling content, this pedagogy required students to develop evidence based reasoning, face moral concerns surrounding controversial issues, and as a result builds conscience on top of scientific skills (Zeidler, 2014). Similarly, problem-based learning presents students with a challenge that is seemingly non-academic in nature. By intriguing them with an experiment with no apparent right or wrong answer, this pedagogy encourages small groups to use trial and error and discussion to come up with possible solutions to the challenge they are facing (Harper, 2017).

STEM education has grown in Pennsylvania and other parts of the United States, and can combine many of the above methods for teaching science (Education Commission of the United States, 2018; Feder, 2015; Falk et al., 2017, Harper, 2017). The paradigms focus on the connections between science, technology, engineering and math which in turn encourage complex, real-life examples incorporating concepts from each subject (Zeidler, 2014). However, first-hand experiences include more than just first-hand activities. In addition to computer-based studies, projects that examine the relationship between STEM and society engage students in the impact science issues have on their communities (Feder, 2015). Whether a teacher uses traditional lecturing, socio-scientific inquiry approach or organizes their classroom with problem based learning, the most effective science education is purposeful, relevant, and collaborative (Falk et al., 2017; Harper, 2017)

Resources

Pedagogies vary in Pennsylvania and around the world, but available resources greatly impact how teachers are able to teach. To successfully engage students in science, classroom resources need to include more than just textbooks (Cobern, 2000; Falk, 2017; Harper, 2017; Liu, 2018; Noble et al., 2012). In fact, for problem-based learning, textbooks and worksheets are not necessary, and students learn actively instead of passively (Harper, 2017). Regardless of teaching style, science classrooms should be equipped with books and magazines with interesting, relevant material (Falk, 2017). Media pieces such as documentaries, news, or television shows can also be introduced as part of a lesson or for students to watch on their own time. Whenever possible, literature should reflect the multicultural, diverse science community, rather than the traditional focus on the accomplishments of dead white men (Cobern, 2000).

In addition to reading material, resources for activities and the opportunity to visit science centers are also important for successful classrooms (Falk, 2017; Harper, 2017). In fact, studies have found that while engaging science activities in the classroom increase student engagement and performance on tests, only science centers and experience watching science-related television had significant impacts on lifelong-science interest (Falk, 2017).

While tangible resources are a vital part of successful science education, teachers also need support and guidance from the administration to plan and carry out engaging lessons (Harper, 2017, Zeidler, 2014). Because pedagogies like socio-scientific inquiry are much more difficult to plan than traditional lectures, institutions need to provide resources for activities, and allow for flexibility and creativity when arranging lesson plans and activities (Zeidler). These plans do not necessarily need to be elaborate; one school incorporated gardening to teach principles such as geometry, math, biology, and engineering (Harper, 2017). However, to carry out such innovative activities, teachers must look to school leaders to remove barriers such as rigid curriculum scope and sequence.

The quality and quantity of available resources is often affected by the socio-economic or even racial demographic of schools (Cobern, 2000; Education Commission of the United States, 2018; Noble, 2012). A lower number of resources is the most cited reason for test score disparity among schools with a high number of minority students (Education Commission of the United States, 2018; Noble, 2012), and the resources many schools have available do not appropriately reflect the school's demographic (Cobern, 2000; Feder, 2015). Several schools in Atlanta, Detroit, and Washington DC introduced texts which mindfully included the contributions and work of African and African American scientists. Feder also cites the importance of providing role models in STEM for culturally and linguistically diverse students, not only in books, but also in their community (2015). One possible way to provide role-models is inviting scientists into the classroom to interact with students. Meeting individuals who work in STEM fields may help students realize the real-life applications of the material they learn in class. After-school programs are an important resource for increasing students' involvement and interest in science, and the absence of high-stakes testing in these programs allows for greater flexibility in activities and inclusive approaches. Afterschool programs require a lot of time and coordination to plan, but an increasing number of grants providing resources for STEM activities make these programs a part of the solution to engaging diverse students in the sciences.

Science standards, educational pedagogies, examination style, and resources may vary from school to school in Pennsylvania, but based on the literature, general trends exist across the state. Individual teaching styles and available resources shape students' experiences in the classroom, but statewide regulations on standards and examinations make it possible to compare science education as a whole. While this may be true in Pennsylvania, this study looked to see how science education compared in The Gambia and Buenos Aires, Argentina. A number of research questions we used to guide the investigation.

III. Research Questions

1. Do science standards in Argentina and The Gambia look the same as those in the Pennsylvania?
2. What resources are available to science teachers and how do they impact what instructors are able to teach?
3. Is the scientific literacy being promoted related to producing career scientists or creating a scientifically informed general population?
4. What do science assessments look like around the world?
5. Do countries outside the United States have a paradigm like STEM?
6. Do science teachers use inquiry or socio-scientific issues approaches, or is the traditional lecture-based instruction predominant?
7. Does science look different because of cultural differences between countries? How might these differences impact students?
8. Is there a best science practice?

IV. Methods

While paradigms like STEM clearly define the aims of science education and the ways teachers can achieve this, my experiences abroad led me to question whether a single "best practice" exists, and in what ways science education might differ in various cultures. Buenos Aires, Argentina and The Gambia were selected for comparison with Pennsylvania. By selecting the autonomous city of Buenos Aires and the state of Pennsylvania as opposed to the entire country, the population of the areas in question were closer to that of The Gambia, as well as confining the research to a more achievable geographic.

Due to the wide range of literature and resources available in the three locations, several methods were used to compare science education in Buenos Aires and The Gambia to the practices laid out in the literature review. One step was meeting with administrators and science faculty at the University of the Gambia and several secondary schools in Pirang, Banjul, and Serrekunda. In Argentina, meetings were conducted at the University of Belgrano, the public secondary school Escuela de Comercio Dr. Antonio Bermejo and the private bilingual school Colegio Horacio Watson, all located within the city of Buenos Aires. Faculty members were interviewed about their thoughts and insights on their experience with science education, and the strengths and challenges they felt were present in their school. These experiences were compared to my own interactions with administrators and science teachers during my placements for the education track at Elizabethtown College. Taking a course load including a variety of science courses has given me further insight into education at a college level

In addition to personal anecdotes, textbooks, assessments, curriculum documents, science standards, and other relevant data were gathered for comparison. These sources were analyzed alongside available articles about science education, pedagogies, and paradigms. The results of this qualitative analysis look to highlight the similarities and differences that exist between the three locations, recognizing that in most cases, best practice varies given the different cultural backgrounds, materials available, and established educational paradigms.

V. Results

Based on the personal anecdotes and materials collected in The Gambia and Buenos Aires, several trends became apparent. While the standards outlining science information was generally the same across all three locations, differences in teacher training and cultural norms impacted the style of classrooms, as did the resources available to school districts. Unsurprisingly, schools in lower socio-economic areas were less able to implement science practices and provide hands-on learning activities for their students. All three areas of interest have new movements promoting science and technology in schools, although the end goals are influenced by the developmental goals of the country. As a science teacher, what struck me most was the way dedicated educators adapted to whatever level of resources was available to them in order to best serve their students and prepare the next generation of scientists.

Structure of Science Classes

One major finding from analyzing documentation outlining science education is the lack of structure in comparison to the regulations found in Pennsylvania. While both the Pennsylvania Academic Standards and those outlined by NGSS clearly break down required content into units and sections, science standards in Argentina are very loosely defined, and instructors have a lot of freedom in deciding what topics to cover in their course. In addition to teaching content, schools are also expected to teach the values, social norms, and behaviors expected by society in all classes (Ministerio de Educación, 2014). This expectation ends up setting schools farther apart when it comes to covering content; public schools typically spend more time on correcting behavior than instruction in subjects like math and science. As stated above, the social inequality in Argentinian society means that students in public school tend to have fewer resources at home, and the time teachers take to address this lack of knowledge leaves less time to cover material.

Behavioral issues aside, science classes are expected to teach conceptual and procedural content, defined as the learning of facts, dates, and ideas as well as the strategies and abilities necessary to achieve in future careers and as a successful citizen (Ministerio de Educación, 2014). Unlike prior regimes, the movement Secondary Schools for the Future goes into detail into what entails. For physics classes, taught during the fourth year of secondary school, the defined sections are energy – kinetic, potential, and gravitational, forces and work, light. Each main area includes the principle ideas and abilities, and suggestions for activities and connections to best teach the content (Appendix B). These standards are specific while leaving teachers flexibility to adapt material to fit their students' interests and needs, accounting for the resources they have available.

While science standards in Argentina are loose at best, I was unable to find specific documentation stating science standards at a national level in The Gambia. However, by using textbooks, exams, and published policy reports, it is possible to determine the standard material taught in science, specifically physics classes. In Nusrat Secondary School, physics education is split over the course of three years. The first segment covers measurements and simple machines, and introduces forces, work, and motion, both in fluids and the more classic cases for objects moving in a straight line (Koidia, 2018a). By second year, students continue motion with projectiles, and are introduced to waves in the form of heat and light (Koidia, 2018b). The final segment covers modern physics, with subjects ranging from atoms and nuclear fission to electricity and magnetism (Koidia, 2018c).

Science Standards Reflected in Examinations

The wide range of content material considered as standard for physics education is further reflected in the nation-wide physics exam. The physics teacher allowed me to look through one of the 2019 exams. It was comprised of two parts: a section with roughly 40 multiple choice questions, and a short answer portion consisting of twelve experiments or models that could be found in a physics lab.

As seen in Figure 1 (Appendix C) one example of an open-ended question asks students to explain the structure and function of a typical photocell, and calculate the result for a realistic scenario involving the device. The emphasis on real-life application on a standardized test is evidence that in addition to science or physics content, practical applications and science competencies are also an important part of Gambia's science standards. Regardless of students' eventual career, those enrolled in physics sit the same exam emphasizing practical skills, with modern applications that create a scientifically literate population. Although the lack of resources for laboratories may limit the extent to which students across the country are able to develop these skills, their prominence on the national exams indicate their importance and the government's focus in continuing to grow and develop the sciences.

While science standards in The Gambia are clearly defined by the content found in the country's standardized tests, Argentina does not have any nationalized exams except for language evaluations. The Ministry of Education does lay out "minimum content" for courses, so classes in biology, mathematics, or literature more or less contain the same material nationwide. However, without a system of standardized testing, meeting these requirements is left up to the individual teachers, who may design their lessons and examinations as they see fit, following the guidelines of their individual school (Binta J., personal interview, May 19 2019; Edward M., personal interview, May 22 2019). However, this has led to the previously mentioned disparity in the quality of education between public and private schools.

In light of the lack of standardization from previous educational regulations in curriculum and examinations, the Autonomous City of Buenos Aires has developed *Nueva Escuela Secundaria* (NES), also known as Secondary School of the Future, a movement towards a new type of secondary education. NES does not propose to create a standardized test or to require more structured exams, but educators do need to apply to the standards laid out regarding digital literacy, and submit progress reports on the main learning objectives of the class (Marina S., personal interview, October 23 2019). Classes are required to include at least three instances of evaluation every trimester, and provide evaluations that can be adapted for distinct learning styles, abilities, and attitudes. Most importantly, the evaluations are tools for understanding students' learning. Teachers are instructed to include pre-evaluations and formative assessments in addition to the final assessments that count towards a student's grade (Ministerio de Educación, 2014).

In addition to these general outlines, NES also recommends the following guidelines for physics evaluations and examinations: participation in group discussions where the students can express, explain, and discuss results of observations and or experiments completed in a lab, written assessments comparing the knowledge of the students with their starting point as well as the knowledge of the other students, and the creation of projects or experiments developed in a research environment (Ministerio de Educación, 2014). In other words, students should not be passive learners, but actively engage in horizontal learning that incorporates the ideas and contributions of both the teacher and students. The emphasis on oral and written production as a way of reflecting on the subject matter is not specific to physics, but builds on the scientific practices of observation, analysis, inference, conjecture, argumentation that are also the goals of NGSS.

While the goals laid out by NES match closely with the model in the United States, in practice, exams may look very different. In one example of a math test from Colegio Watson, the entire exam was less than a page long, with problems that closely mirrored the practice packet written by the professor. Students were asked to find the solution for three equations, and the fourth question was a word problem with a practical application about the cost of pies in a bakery (Figure 2, Appendix B). The test was much shorter than exams often given in the United States, but the length allows teachers to give assessments more frequently, and is easier for the many teachers who have to balance working in more than one school

These exams are an excellent demonstration of the parameters for testing set by NES, and paired with other methods of evaluation such as lab reports and online projects, are a representation of the integration of student centered-learning encouraged by STEM. While some schools are making great progress towards these goals, international tests show that Argentina is still falling behind. Figure 1 in Appendix B shows the performance of public and private school on the Trends in International Mathematics and Science Study (TIMSS).

A breakdown of the scores shows that nearly 30% of students in private schools score below basic, while in public schools that figure rises to over 50% (Guadagni, 2019). This international evaluation is not required, nor is it a representation of every school in the greater Buenos Aires. However, the large percentage of students failing on the international performance marker show is that while progress has been made, Argentina still has a ways to go to reach international standards.

While Argentina is distinct in its style of examinations, as far as standardized testing is concerned, the Gambia is more like the United States. End of the year exams closely resemble

Pennsylvania's Keystones, with the resulting scores used to evaluate schools. These standardized exams utilize multiple choice comprehension questions and a short answer practical section, where students apply their knowledge of experimental science to respond to questions based on images and real-life examples (cite test here).

One marked difference between Pennsylvania's standardized tests and the evaluations in the Gambia is that while the former are taken online, facilitating grading, the latter are submitted in paper packets, causing feedback to be greatly delayed. When results do arrive, performance between schools across The Gambia and even within subjects varies greatly. As shown in Figure 3 (Appendix C), Gambian students struggle most on science subjects, scoring lowest on biology, chemistry, and physics (Ministry of Higher Education, Research, Science and Technology, 2014). Unfortunately, the score report available to me did not break down grades on individual sections; however, it seems likely that with the vast majority of schools lacking laboratories, the practical section would pose the greatest challenge to test-takers. The score report is valuable data, demonstrating the need for continued development in the sciences. Low scores limit Gambian students looking to continue their education in biology, chemistry or physics at university level, thus constraining the number of future scientists and innovators. On the flipside, Argentine students are free to enroll in any university program without proving their competence in the subject. As a result, a higher percentage of Argentine students who graduated from public school drop out in the first year, unable to keep up with the rigorous content (Universidad de Belgrano, 2019).

Whether held back by test scores or limited by the level of material taught, the principle disparity holding back students seems to be based on socio-economic level. Simply put, students from low-income families cannot afford the resources needed to be successful in school. Especially in schools pushing to move towards the international standards with hands-on applications, textbooks, lab materials, and even internet access at home serves as a barrier to success. These setbacks early on continue to be roadblocks to success as students advance through school, as lack of resources and low grades make it difficult for students from low socio-economic backgrounds to be accepted into private schools. Stuck in low-funded public schooling, these students can become trapped in a vicious cycle.

Science Pedagogies in Argentina

Another major finding of this study was the pattern of pedagogies found in the three locations. Defining a standard pedagogy to an area is complex, as every teacher uses a different style to manage their classroom. Despite this limitation, classroom observations and published policy showed a trend in the way material was shared. In the goals and recommendations outlined by NES, the framework pushes towards a constructivist pedagogy, adopting projects and inquiry based learning to put students at the center of their own education (Ministerio de Educación, 2014; Ministerio de Educación, 2015). In the guide *Formación general*, it is stated that a successful physics class should teach the subject content such as energy and forces, but also highlights the importance of teaching students how to read tables and charts, and stresses the incorporation of authentic scientific texts and journals as part of the course material (Ministerio de Educación, 2015). To best teach the recommended skills and competencies, the Ministry of Education identifies functions of science, and the activities that promote each section. The six sections of science that all pedagogies should incorporate are abstract, analytic, symbolic, esthetic, creative, and empathic (Ministerio de Educación, 2014).

Abstract refers to students' capacity to distinguish the principal concepts to those on the periphery. Conducting experiments with controls and analyzing the results is one way to teach students to identify key factors and understand how outlying data or accidental changes can lead to misleading results. Labs also contribute to the analytic function, in which students learn to classify and discover relationships. The requirement for "discussions that allow the exchange of opinions among students, promoting reflection around the diversity of perspectives" (2015, pg 205) ties into the symbolic function, which refers to students' use of technical vocabulary when talking about scientific concepts, and the development of scientific writing (2014, p 98). The ministry does not limit this writing to lab reports, but stresses the importance of mastering imperative, persuasive, and interrogative writing.

The esthetic and creative aspects of science are closely related, and tie together with the idea of STEAM: the incorporation of the arts in hard science. While learning content and incorporating real-life applications may be a priority, in addition to being functional, science can be visually pleasing. The idea of "upcycling art" in Buenos Aires follows this trend (Iberdrola, 2020). From murals on school buildings made of colorful bottle caps to an exhibit in the Palacio de Aguas Corrientes using art as a means to teach about recycling and human impact on the planet, including creativity into science models has become increasingly popular. Allowing students to do similar activities on a smaller scale may be time consuming, but incorporate valuable skills that are also important when marketing science inventions to the general public; it is easier to sell a product that is esthetically pleasing.

Finally, the empathetic function serves to promote dialogue, responsible decision making, and the ability to tolerate differences. Science is often presented as a series of facts, but an article in the educational magazine *Pedagogical Dialogues* argues the importance of presenting controversial scientific ideas to the classroom (Miguel, 2018). Like Cobern, the article reminds readers that the scientific knowledge available in every era is not a perfect or infallible explanation of our world, but merely the best-known version based on past experiments and known phenomena (2001) & (Miguel, 2018). Cultural and social practices may impact what information is seen as credible in different societies, and receiving only the knowledge that is "finished and agreed upon without the uncertainties and controversies pending resolution" (Miguel, p 64) limits students in their ability to understand and evaluate the world around them as well as their formation as responsible citizens.

Learning that it is not always possible to find an immediate answer to a problem is an important empathetic function, as is working to resolve problems without a clear-cut solution (Ministerio de Educacion 2014). For this reason, while Miguel's specific example of climate change may not fall directly into one of the designated content areas for a physics classroom, it is an excellent model for introducing controversial and complex issues to high school students. From looking at the role of human activity such as the release of carbon dioxide, to natural processes magnetic and solar interactions, learning to analyze the many complicated and interrelated causes of a pressing and impactful issue stresses the importance of science in the lives of every student, whether or not their career will be part of the STEM field.

In the classes I was able to observe, professors followed a constructivist pedagogy to a point, encouraging students to answer their classmates' questions, incorporating real-life examples when introducing new information, and asking students to relate those concepts to their own experiences. Even so, limited resources and large class sizes often restricted professors' capacity to assign larger projects or otherwise giver greater control to the students.

Science Pedagogies in The Gambia

Whereas Argentina seems to be moving towards a more student-centered model, The Gambia traditionally follows a very teacher-centered pedagogy. With an approximate student-teacher ratio of 50:1 in Pirang and closer 30:1 in Serrekunda (classes are split into morning and afternoon sessions to make class-size more manageable), classroom management often takes a priority, and lack of resources makes student-centered, hands-on learning nearly impossible. Pedagogy is also heavily based on instructors' experiences and training. English may be the official language of the Gambia, but most students speak another language, such as Wolof, Mandingo, Pulaar, and Jola at home. Teachers focusing on language instruction and enforcing behavior have little time remaining to implement student-centered activities without special training.

While lectures are the prominent model for teaching information, schools in the city are moving towards a more student-centered model. Nusrat Senior Secondary School has begun sending its teachers to summer training sessions to learn new ways to incorporate students in class. Whereas in the past professors would spend the entire period lecturing by the blackboard with students taking notes, now the first fifteen or twenty minutes is devoted to students to ask questions. Teachers also make an effort to ask for input during the lesson, such as letting students help explain part of an example problem. One instructor explained their pedagogy for participation as being "think-pair-share," a phrase I have heard frequently during my preparation as a science teacher in Pennsylvania. The idea is to encourage students to work on their own or in groups of two on challenging problems before discussing as a class, promoting self-efficacy and encouraging students to potentially approach problems with various techniques. Think-pair-share is an effective strategy, but fifteen minutes at the beginning of the class for student participation is a far cry from being truly student-centered. Nevertheless, entirely lecture-based classes are still considered the norm, the few Gambian schools striving to modernize their pedagogy have made excellent progress in a short period of time.

With formal teacher training lasting only a year in The Gambia before a two-year apprenticeship (Jainaba Darboe, 2019), while a teaching degree takes an average of six years in Argentina, it makes sense that this disparity would be reflected in teaching style. However, based on interviews with teachers in both locations, it seemed the resources available had a greater impact on their teaching style. Lack of resources certainly hinders NES's push towards student engagement. Having resources and materials for labs and hands-on activities is essential for lessons that push students to contribute to their own learning. The city of Buenos Aires is better off than most parts of Argentina, where it is common for schools to have one laboratory shared between classes. As 88% of schools in Latin America don't have even one, Buenos Aires is making progress; however, the challenge of costly equipment and supplies impacts other parts of the classroom as well (Vicuña, 2018).

The Impact of Available Resources

During my observations of Argentinian schools, one of the first things I noticed resource-wise is that the vast majority of classes don't have textbooks. It simply is not practical to require students to buy a book for each class, nor can the schools afford a class set (Ricardo G., personal interview, September 23 2019; Sergio L., personal interview, October 1 2019). The one exception was in a biology class, in which all students had a copy of the book Biología 1, which interestingly is published by NES. One defining aspect of the textbook that I have not seen in other places was the inclusion of a page or two at the end of each chapter giving a real-life example from Argentina. For instance, following the section about fungi, there is a short article about Argentine biologist Carolina Barroetaveña, a researcher at the University of Patagonia San Juan Bosco studying the effects of fungi on the forests of Patagonia. Students are then asked to apply the material from the chapter and use this example to further investigate and explore practical science applications (Balbiano et al., 2015).

While NES is starting to distribute textbooks, the fact remains that many schools simply cannot afford them. A typical solution for a lack of literature is for teachers to scan the most essential parts of a textbook to share online through sites like Canva or Genially (Marina S, personal interview, September 19 2019; Ricardo G., personal interview, September 23 2019). However, while this was an effective solution in the private school Colegio Horacio Watson, the fact remains that students living in poverty do not have the same level of access to digital resources. In one school in Villa 31, the school has a digital space with ten computers for students to use, but none of the students have internet access at home, so their use is limited to whatever free time they may have before or after class (González, 2013). With hundreds of students sharing ten computers and no capacity for printing materials, technology is not a viable replacement for other resources.

With both textbooks and their online counterpart unavailable for a large percentage of students, another solution I observed was teachers writing their own material. One math teacher used the original text as a guide for his lectures, with students taking notes on the key concepts. However, he would then write his own practice problems based on the needs of his students, and print out a packet for each member of the class (Sergio L., personal interview, October 1 2019). Students were still charged for the cost of printing the material, but this price is much more affordable for students. The packet included functions to solve, graph problems, word problems, and pages with images of how to use a graphing calculator to solve similar problems.

Teachers' varied adaptations to replace textbooks are a step to overcoming the lack of resources. Another way schools are progressing is thanks to the work of NES in distributing equipment for activities. In the past year, Escuela de Comercio Número 2 has received kits with circuits, programmable robots, Arduinos for coding, and even a 3-D printer. The school has also been equipped with a smart classroom whose professor Daniela Palacio, and digital pedagogical assistant Marina Scalerandi have been trained to use and incorporate technology into classroom activities. During one of my observations, students used sites like Geogebra to highlight geometry in artwork by Da Vinci, and used the tools on the site to make geometrical shapes in the paintings move in the program (Palacio, 2019). The assignment combined knowledge from their art and math classes while teaching how to use the new technology.

While lack of resources may be a challenge in Buenos Aires, the situation in the Gambia brings this problem to an entirely different level. Students are required to pay for their own textbooks and uniforms (Binta J., personal interview, May 19 2019), which is a challenge when minimum wage is roughly one US dollar a day and the average family has five or six children (Ministry of Higher Education, Research, Science, and Technology, 2014). Government funding and outside sponsors help to furnish classrooms and laboratories, although the latter may mean schools receive second-hand books or resources designed for other countries (see Figure 2 in Appendix C). For example, one primary school featured posters of animals with labels in Dutch (Pirang Nursery School). However, it was paired with hand-made posters showing fruits and vegetables native to The Gambia. Other creative adaptations included using recycled bottle-caps as counters to teach basic math.

Despite the best efforts of instructors, with a few exceptions, Gambian classrooms just don't have the capacity for hands-on student activities. The only school where I saw a fully functioning laboratory was at Nusrat Senior Secondary School, generally regarded as the best high school in the country. According to Principal Karamo Bojang, this is mostly due to prioritizing funds. He chose to pay for a laboratory instead of replacing the old canteen, and while from the outside the library may appear to be old and run-down, the books that fill it are of better quality than can be found in most Gambian schools (personal interview, May 22 2019). With the highest performance in the country, Nusrat has shown the value of resources in the classroom; however, this level of funding is simply not available in all parts of The Gambia.

As one moves farther east, the availability of resources drops drastically. Much like the case in the villas of Argentina, technology is not a viable solution in these remote regions, although not so much because of the cost as the lack of a reliable Wi-Fi network. However, where it is available, science teachers without the resources to create a laboratory like Nusrat have started to use YouTube videos or online simulations to demonstrate the real-life applications of principles taught in class (Tony A., personal interview, May 21 2019; Edward M., personal interview, May 22 2019).

Despite the general lack of resources, one of the most impressive things I noticed was textbooks that had been made specifically for the Gambia. For example, at Pirang Primary school, the book used to teach English is part of the Gambia Schoolbooks Project, and uses traditional images and familiar names, places, and objects to introduce the alphabet and simple sentence to students (English for Beginners, 2007). Even more advanced science classes at Nusrat Secondary School had textbooks designed specifically for them, although it is unlikely that schools with less funding would have access to such a personalized resource. Author Samuel Koidia designed the series of three books to prepare students for practical experiments and to succeed in the national exams. The text does not only include explanations and practice problems, but numerous images of scientific equipment, so when students start participating in labs they are more prepared to use materials they were likely not exposed to in any other part of their life (2018).

The Goals of Science Education

My final major finding was how the educational paradigms present reflect the country's goal for education. The way science is valued in the community is directly tied to how it will be approached in a school setting. A curriculum with the primary goal of preparing students to pass an exam will take a very different approach from one whose aim is to create career scientists, or one looking to form a scientifically informed society. In Argentina, the goals of scientific literacy are multifaceted. For one, the government recognizes that STEM education is vital to prepare citizens to face the challenges of the 21st century (Sociedad Científica Argentina, 2018). Traditionally, schools waited until the end of primary or the beginning of secondary to begin pushing vocations in science, technology, and engineering; however, the growing importance of STEM careers in society has pushed students to develop skills and interest in these fields at an earlier age (Iberoamérica Divulga, 2018). In fact, reports by the World Economic Forum estimate that 65% of the students entering schools today will work in jobs that don't yet exist. Their futures will be guided by advancements in science and technology, and their schooling should adapt to prepare them accordingly (Schulkin, 2018).

STEM education is also practical for students at an economic level, both personally at a country-wide level. Another reason Argentina is pushing to modernize their science education is a means to resolve the economic challenge the country faces. By partnering with UNESCO, Argentina has joined the pilot project for STEM and Gender Advancement (SAGA). Through this program, the government of the Autonomous City of Buenos Aires, also known as CABA, has started working to diminish gender disparity in the science fields while pushing for growth in STEM in schools in Buenos Aires (Iberoamérica Divulga, 2018).

Implementing STEM is an attractive goal because of the way it can be used to problem solve local problems in everyday life. The Ministry of Education wants students to value the importance and utility of science. In other words, the objective of science education is not necessarily to create career scientists, but a scientifically literate society capable of solving the country's various economic challenges. The Ministerio de Educación more clearly outlines its goals of scientific literacy in the learning objectives listed in the 2015 guidebook for NES:

- Recognizing the distinct ways in which energy can be manifested and relate this with the capacity to produce distinct types of effect
- Predicting the evolution of a system in response to different changes in the environment and its own dynamic evolution as an isolated system, based on the model that best describes said system

- Quantitatively interpreting the existing relations between the variables involved in mechanical processes, including those in the form of waves and vibrations, using mathematic concepts as tools
- Distinguishing between scalars and magnitude vectors
- Distinguishing and comparing the different types of motion
- Explaining physics phenomena found in everyday life using Newton's Laws
- Recognizing situations in which the conservation of energy is in play, and establishing the relation between work done and transformation of energy
- Distinguishing between when light acts as a wave and when it acts as a particle
- Analyzing, interpreting and constructing graphs and diagrams
- Designing and carrying out experiments
- Using symbolic language and specific science vocabulary accurately (pg 199)

While much of the list is the ability to demonstrate content learning, the final three are general science skills not specific to physics. Rather they emphasize a way of thinking and a competency for scientific language that can be applied in any field. These skills cannot be so easily tested on an exam, but must be proved through opportunities to put their learning into action with peers, discussing, creating, and putting science into practice in their own lives.

Much like the goal for economic growth in Buenos Aires, my experience in The Gambia led me to believe the main goal of science education is to promote development as a nation. Because it is such a small country, progress in The Gambia may not necessarily look the same as it does in the United States; however, technological advancements create opportunity for innovative solutions to the problems faced in the West African nation (Ministry of Higher Education, Research, Science, and Technology, 2014; The Ministry of Basic and Secondary Education, 2014). In addition to the evidence for the value of practical science skills on national exams, recent policy looks to harness technological and scientific advancements to create a more vibrant and sustainable socio-economic country (Ministry of Higher Education, Research, Science, and Technology, 2014). The long-term objectives foresee science educations as a means to modernize agricultural practices, incorporate indigenous technology and traditional knowledge into safe, contemporary medical applications, and incorporate technology and problem-solving skills into resolving socio-economic problems (2014).

Scientific Paradigms

These goals of problem-solving, reducing poverty, and promoting national growth are directly tied to scientific paradigms in the city of Buenos Aires and The Gambia. Inspired by the growth of STEM programs abroad, the Sociedad Científica Argentina (SCA) partnered with schools in the province of Buenos Aires in the beginning of the 2018 school year. Following the example of programs in the USA and Canada, this program looked to incorporate ways for students to take the theoretical skills from their science and math courses and put them to practice by designing and constructing their own solutions to problems in technology and engineering (Sociedad Cientifica Argentina, 2018). Although the pilot experiences were only offered to 4th, 5th, and 6th grade classes, directors of Escuela Municipal Manuel Dorrego de Florida Oeste noted that the integration of programming, circuits, and robots into previous curriculum have made students more enthusiastic about the content (Schulkin, 2018). The founders originally focused on STEM at the primary level, in part because the program was easier to implement for younger children, but also because of a growing sense of urgency to form interest in STEM subjects at a young age. Technology and activities that promote "hands on, minds on" activities have spread with the help of government programs, and their growth in turn is helping Argentina reach its goal of preparing students for the twenty-first century.

While the idea of STEM education exists in Argentina, NES is a much more prominent educational paradigm. The new curriculum design envisions the transformation of students from passive learners to active participators in the creation of diverse educational processes (Ministerio de Educación, 2014) & (Ministerio de Educación, 2015). NES stresses the importance of each student as an individual, and seeks to guarantee that each child can exercise their right to a quality education. Every student should be given the tools to develop their potential and the competencies necessary for their personal and social success, and in order to exercise their responsibilities as a citizen of Argentina. The curriculum is a direct response to the objective of the Ministry of Education to develop authentic education that includes the knowledge, attitudes, values and abilities of the twenty-first century (Ciclo basico, pg 43).

The implementation of the curriculum designed by NES seeks to prepare students to continue higher studies, and to incorporate a core of basic knowledge to integrate into the world of work. To this end, special attention is paid to the retention of students, ensuring the quality of the teaching, and achieving learning objectives. The paradigm may not be specific to science education, but it is the biggest reform in science education in Argentina, and the only one in Buenos Aires addressing the greatest challenges in the STEM fields.

One major challenge facing Secondary Schools for the Future in producing a significant impact on student learning is to transform the teaching practices and forms of institutional organization (Ciclo Basico). In this sense, the school must ensure the necessary means "for the construction of relevant school careers, in an environment of care and confidence in the educational possibilities of all” (pg 44) and providing avenues for students to discover and explore their interests, expectations, and vocations. This is especially difficult when not all students are able to continue studying at university level, or are otherwise limited in the field work and internships because of their socio-economic level (ArInfo, 2019).

Due to its size, it is unsurprising that The Gambia has not implemented a paradigm like STEM to the same extent as Buenos Aires or the United States. One of the engineering professors at the University of the Gambia shared his work in creating a society that connects professionals in the various fields (Tony A., personal interview, May 25 2019). Members travel to schools to help promote interest in the sciences. Despite their efforts in this regard, I did not find evidence that STEM is regularly incorporated in schools. However, recent policy looks to introduce a combination of science and technology into Gambian classrooms. The movement for Science, Technology, and Innovation (STI) is a response to the national goals to achieve poverty reduction, competitiveness, sustainable environmental management and industrial growth (The Ministry of Basic and Secondary Education, 2014; Ministry of Higher Education, Research, Science, and Technology, 2014).

Teaching science and technology together is vital to increase understanding of the way science and technology affect, among others, the fishing, transportation, and agricultural industries. Recent innovations or improved practices could increase efficiency, but education is needed for these changes to be accepted in the society. The modernization of fishing and farming techniques used for generations are met by resistance despite their increased efficiency. When these practices are integrated in the education of science and technology, these innovations become more normalized. If continued, science education should help The Gambia meet its goals of reducing poverty and improving sustainability and competitiveness through advances in the economy.

VI. **Discussion/Conclusion**:

My experiences in the classroom and opportunities to interview and collaborate with administrators and science educators in The Gambia and Buenos Aires were invaluable for understanding their respective education systems. However, my research was limited by several factors. While I was given access to exams and textbooks during my time in The Gambia, finding resources online, especially country-wide standards was a challenge. My visit was also only two weeks long – much shorter than the time I had to investigate in the other two locations. I spent five months studying abroad in Argentina, and thus had a much longer exposure to their education system and more time to visit schools. Even so, language was occasionally a barrier. As a non-native Spanish speaker, it was difficult to discuss nuances of the education system with teachers. I had a much more extensive access to documents published by the ministry of education, but navigating through lengthy literature in Spanish was a further obstacle. While I may not have the opportunity to continue this study in Argentina or The Gambia, this research will continue to be shaped through practical application in my own classroom.

This is not to say determining and implementing a best practice from among the three locations is simple. From a purely numerical standpoint, one could argue that Pennsylvania and the United States have the superior education system based on the percentage of students who graduate and the physical resources available for teachers and students. However, this conclusion ignores the historical and cultural context in Argentina and The Gambia. Although I was surprised by the living conditions and lack of resources available in many of the schools in The Gambia, I also saw some of the greatest resourcefulness among their education system. Although it counts among the minority, Nusrat is a shining example of what the future of science education in the country may be. Reliable internet access and the materials necessary for laboratories will probably not become common in the eastern part of the country in the next decade. In this regard, The Gambia will have to continue struggling to play catch-up. However, the United States and other leading world powers could take a note from Gambian efforts to use scientific advancements to make their practices sustainable.

Since Buenos Aires is often referred to as the Paris of South America, before my study abroad experience I expected the education system in Argentina to closely mirror Europe and the

United States. I underestimated the lingering impacts of European imperialism on South America. While large cities like Buenos Aires have adopted the culture of western society, it is still easy to see the economic inequality that disproportionately affects racial and ethnic minorities. Even in the capital Buenos Aires, education is drastically impacted by socio-economic level, and the marked differences between public and private education influence the likelihood for success. Like The Gambia, the amount of resources available seems to be the biggest roadblock for science education. However, I was impressed by NES, and I believe we can learn a lot from CABA's movement to restructure science in the classroom. Their focus on abstract, analytic, symbolic, esthetic, creative, and empathic functions of science makes for more applicable and relatable lessons.

Additionally, while the lack of accountability from teachers and schools poses problems, the lack of standardized testing in Argentina is another strength of their education system. This system trusts teachers and gives them the freedom to structure their class the way they feel is most beneficial instead of requiring them to teach to a test.

As a future science teacher, it is important to recognize that while the many analyzed methods appear totally different, each has the overall goal of preparing students and society to adapt to scientific advancements. My own students will likely be just as diverse as some of the classrooms I observed. From differences in language and religion to ethnicity and socioeconomic background, it would be foolish to think that one style of teaching will work for all students. Teachers in Pennsylvania, Buenos Aires, and The Gambia adapt their teaching styles to fit the culture and established paradigms at their schools, but given our common goal I will use what I have learned to make my classroom more engaging and better equipped to educate all students.

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Appendix A:

Figure 1 *Science learning goals by age group in Pennsylvania*

Grades K-4	Grades 5-7
• Distinguish between scientific fact and opinion. • Ask questions about objects, organisms and events. • Understand that all scientific investigations involve asking and answering questions and comparing the answer with what is already known. • Plan and conduct a simple investigation and understand that different questions require different kinds of investigations. • Use simple equipment (tools and other technologies) to gather data and understand that this allows scientists to collect more information than relying only on their senses to gather information. • Use data/evidence to construct explanations and understand that scientists develop explanations based on their evidence and compare them with their current scientific knowledge. • Communicate procedures and explanations giving priority to evidence and understanding that scientists make their results public, describe their investigations so they can be reproduced and review and ask questions about the work of other scientists.	• Understand how theories are developed. • Identify questions that can be answered through scientific investigations and evaluate the appropriateness of questions. • Design and conduct a scientific investigation and understand that current scientific knowledge guides scientific investigations. • Describe relationships using inference and prediction. • Use appropriate tools and technologies to gather, analyze, and interpret data and understand that it enhances accuracy and allows scientists to analyze and quantify results of investigations. • Develop descriptions, explanations, and models using evidence and understand that these emphasize evidence, have logically consistent arguments and are based on scientific principles, models, and theories. • Analyze alternative explanations and understanding that science advances through legitimate skepticism. • Use mathematics in all aspects of scientific inquiry. • Understand that scientific investigations may result in new ideas for study, new methods or procedures for an investigation, or new technologies to improve data collection.

Grades 8-10	Grades 11-12
• Compare and contrast scientific theories. • Know that both direct and indirect observations are used by scientists to study the natural world and universe. • Identify questions and concepts that guide scientific investigations. • Formulate and revise explanations and models using logic and evidence. • Recognize and analyze alternative explanations and models.	• Examine the status of existing theories. • Evaluate experimental information for relevance and adherence to science processes. • Judge that conclusions are consistent and logical with experimental conditions. • Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. • Communicate and defend a scientific argument.

Appendix B:

Figure 1 *Percent of Buenos Aires students with below basic scores. Scores among public, state school are shown on the left, with private school scores in the middle column. The difference between the two is displayed on the right.*

	Brecha de desigualdad. Matemática 5°/6° Secundaria		
BUENOS AIRES	Por debajo del Básico en %	Por debajo del Básico en %	Puntos porcentuales de desigualdad
Partidos del Conurbano	ESTATAL	PRIVADO	
SAN FERNANDO	60,12	22,68	37,44
TIGRE	59,87	25,37	34,50
SAN ISIDRO	49,58	17,36	32,22
EZEIZA	50,24	22,07	28,17
JOSÉ C. PAZ	64,71	38,95	25,76
ESTEBAN ECHEVERRÍA	50,66	24,91	25,75
LOMAS DE ZAMORA	53,98	28,60	25,38
TRES DE FEBRERO	53,43	28,05	25,38
AVELLANEDA	52,35	27,46	24,89
MORENO	60,99	36,68	24,31
VICENTE LÓPEZ	37,23	13,46	23,77
TOTAL	***51,13***	***27,39***	***23,74***
FLORENCIO VARELA	61,22	37,54	23,68
ALMIRANTE BROWN	55,73	32,88	22,85
MORÓN	44,54	21,84	22,70
LANÚS	51,57	30,22	21,35
QUILMES	50,41	30,00	20,41
HURLINGHAM	50,72	30,45	20,27
LA MATANZA	53,01	32,93	20,08
SAN MIGUEL	52,21	34,29	17,92
MERLO	56,75	39,43	17,32
BERAZATEGUI	52,11	34,97	17,14
ITUZAINGÓ	45,78	30,27	15,51
GENERAL SAN MARTÍN	44,50	31,22	13,28
MALVINAS ARGENTINAS	57,27	44,77	12,50

Fuente: Ministerio de Educación, Cultura, Ciencia y Tecnología. Sistema Abierto de Consulta. Aprender 2017.

Figure 2 *Sample math exam for 11th grade students in a private school*

Apellido y Nombre: Tema: Tierra

Evaluación de Matemática
4º Año

1. Resolver la siguiente ecuación:

$$\sqrt{\frac{x^2}{4}+\sqrt{1-x}}-\frac{x}{2}=1$$

2. Hallar el valor de "K" para que las gráficas generadas por las funciones $G_{(x)} = x - K$ y $F_{(x)} = x^2 - 8x + 2$ se corten en un solo punto.

3. Obtener la solución de la siguiente inecuación:

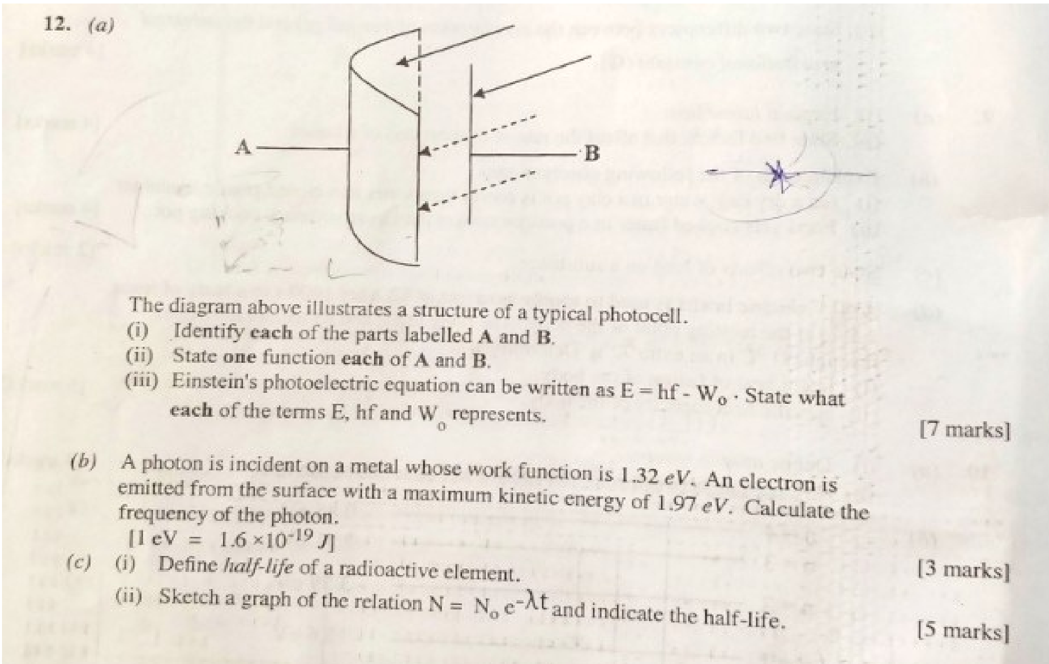
$$4x^2 + x(x+3) - 8 \geq 4(x^2 + x + 3)$$

4. El dueño de una panadería le compra a un repostero pastafrolas pagando un total de $ 5.760.- Si cada pastafrola costase $ 60.- menos, con lo que pagó podría haber comprado 8 pastafrolas más. ¿Cuánto pagó por cada pastafrola? (Resolver analíticamente)

Nota:

Appendix C

Figure 1 *sample open-ended exam question*



12. (a)

The diagram above illustrates a structure of a typical photocell.

(i) Identify **each** of the parts labelled **A** and **B**.

(ii) State **one** function **each** of **A** and **B**.

(iii) Einstein's photoelectric equation can be written as $E = hf - W_o$ · State what **each** of the terms E, hf and W_o represents. [7 marks]

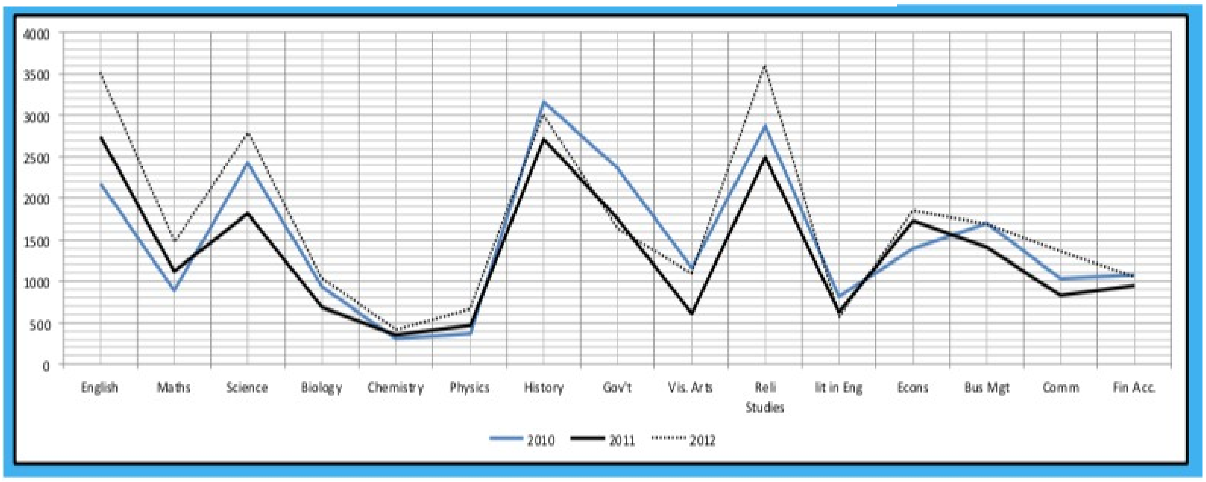
(b) A photon is incident on a metal whose work function is 1.32 *eV*. An electron is emitted from the surface with a maximum kinetic energy of 1.97 *eV*. Calculate the frequency of the photon.
[$1\ eV = 1.6 \times 10^{-19}\ J$]

(c) (i) Define *half-life* of a radioactive element. [3 marks]

(ii) Sketch a graph of the relation $N = N_o e^{-\lambda t}$ and indicate the half-life. [5 marks]

Figure 2 *Gambian-designed workbooks next to board games in Dutch*

Figure 3 *Performance of Examinees in the Major Subject*



Source: Adopted from data received from the West African Examinations Council, Banjul Branch